EXECUTIVE SUMMARY

This report contains a complex analysis of multiple variables that when acting together affect the solubility of arsenic and manganese in Bamberger Pond groundwater. The complexities are shown graphically and interpreted in the text. This executive summary is a simplified overview of the numerous geochemical and biochemical interactions affecting arsenic and manganese solubility in the groundwater.

The geochemical character of the saturated formation at Bamberger Pond is dominated by iron-oxide solubility. Arsenic occurs as a naturally adsorbed metal on the oxide surfaces. Model simulations predict that 11.3 mg/kg of arsenic can occur as the total arsenic concentration through sorption to the formation alone. The conceptualization of the formation's geochemical parameters and interaction with the atmosphere is presented on Figure ES-1.

The biochemical character of the saturated formation is initiated with natural organic deposition in the pond which is measured by total organic carbon (TOC). The source of TOC appears to be decayed leaves, grasses, twigs, and other natural carbon substrates. Anthropogenic activities do not contribute to the TOC in the pond sediment and water. During rain events, surface water runoff transports solids containing TOC into the pond sediment. The TOC then dissolves as it enters the shallow groundwater via recharge through the pond and serves as an extraneous source of carbon for the indigenous bacteria.

Utilization of the carbon occurs during the biodegradation process. Once the available oxygen is consumed, other bacteria utilize alternative electron acceptor compounds, such as iron and manganese-oxides. During the biodegradation process, dissolution of the formation's iron oxide phases occurs, the adsorbed arsenic is released, and the groundwater redox-potential (Eh) is dramatically lowered to values <100 millivolts. This process increases the dissolved concentrations of iron, manganese, and arsenic in the ground water. The metal enriched, low Eh groundwater then flows down-gradient from the pond within a "TOC plume". The highest concentrations of iron, arsenic, and residual TOC are currently observed in wells approximately 250 feet down-gradient of the pond, although elevated metal concentrations and the lowest mean electrochemical potential are still observed within 100 feet of the pond. The conceptual model of these events is shown on Figure ES-2.

During dry periods, the water table lowers and the previously submerged formation is exposed to atmospheric (and more oxidizing) conditions. Evaporation of residual moisture in the vadose zone and probably the water table itself is expected to occur. Evaporation drives dissolved carbon dioxide from the residual water and the pH increases. Model simulations predict that the pH of background water from the area can easily reach levels of 9.0, which is consistent with the elevated levels observed down-gradient of the pond. Evaporation also concentrates the dissolved levels of iron, manganese, and arsenic in the shallow formation. As the pH of the shallow water increases, arsenic is significantly desorbed from the oxide surfaces. Model simulations predict that up to 0.180 mg/L of arsenic can be desorbed from the saturated formation in the 7.5-8.5 pH range. Arsenic concentrations have been measured as high as 0.082 mg/L in the groundwater. Finally, due to the increasing pH, many of the groundwater samples are significantly supersaturated with respect to both manganese-carbonate and iron oxide, thereby hindering kinetics for establishing equilibrium. This kinetic hindrance is responsible in part for the elevated manganese concentrations.

This reaction sequence results in both vertical (redox-dominated) and lateral (transport-dominated) equilibria zones in the shallow saturated formation. The actual system also is affected by multiple redox (rainfall) and evaporation (dry period) cycles that greatly complicate the observed groundwater chemistry, even within a single well.

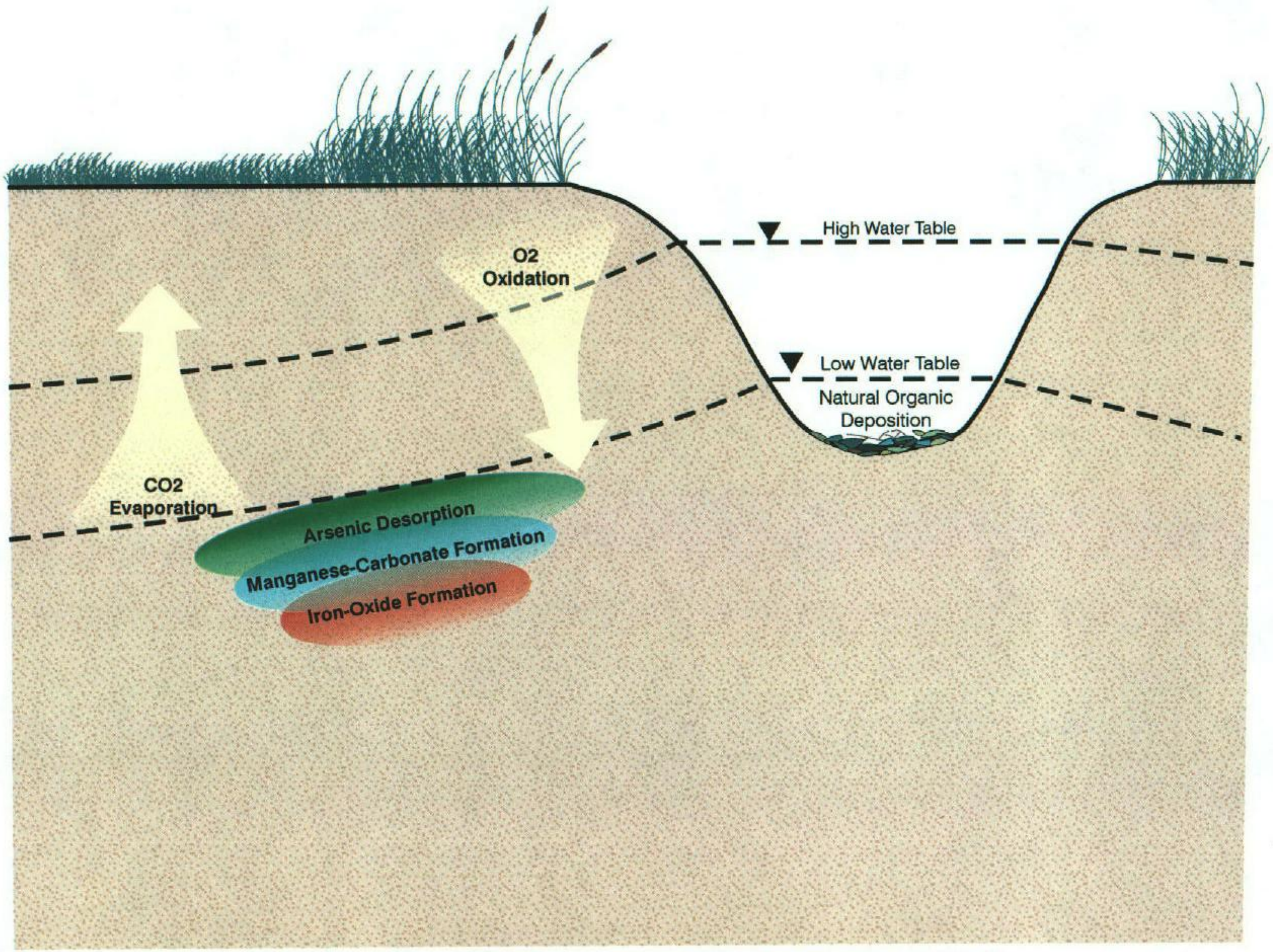

Figure ES-1. Conceptualization of Aquifer Near Bamberger Pond

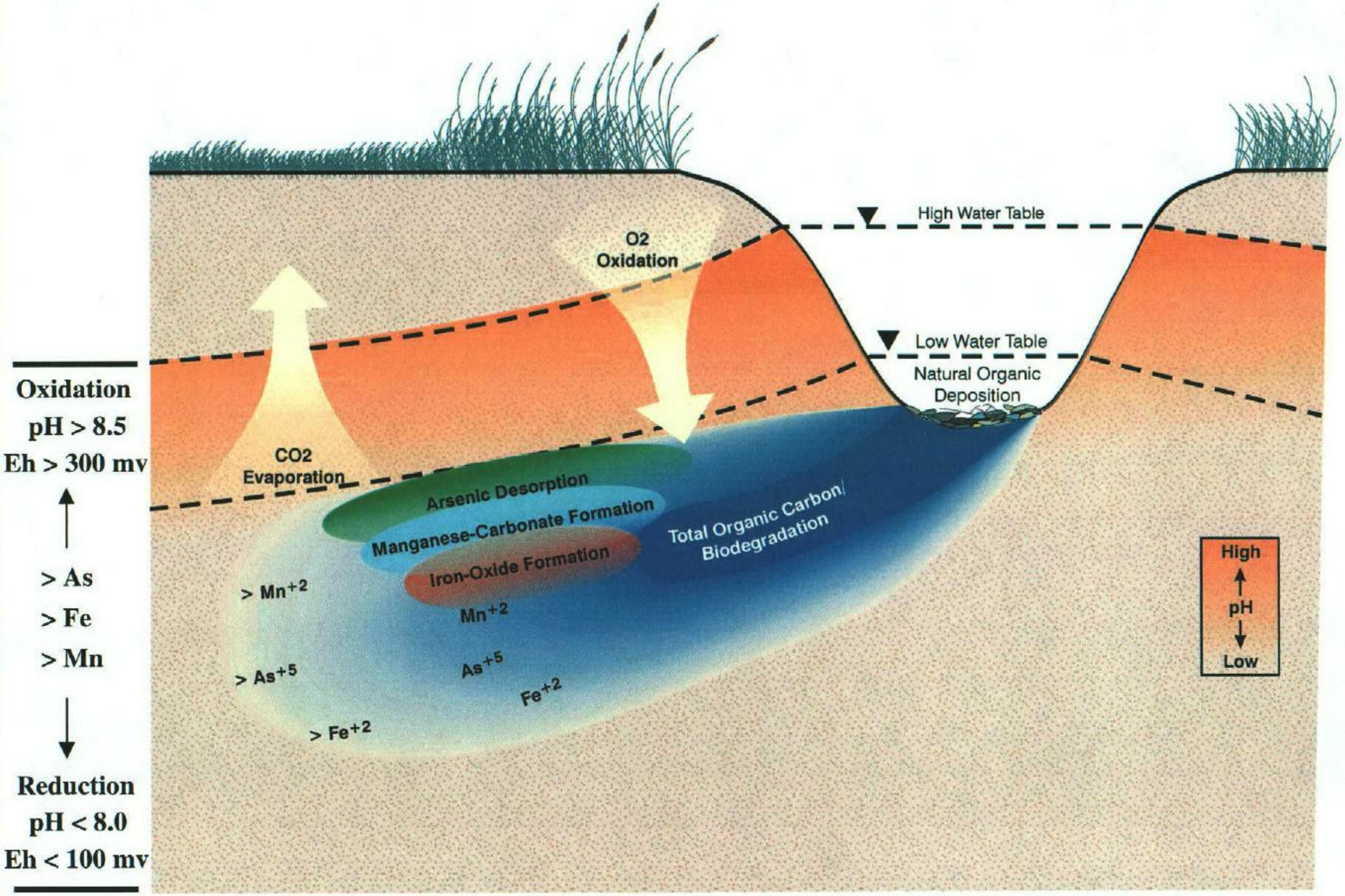

Figure ES-2. Conceptualization of Geochemical/Biochemical Interactions in Aquifer Near Bamberger Pond